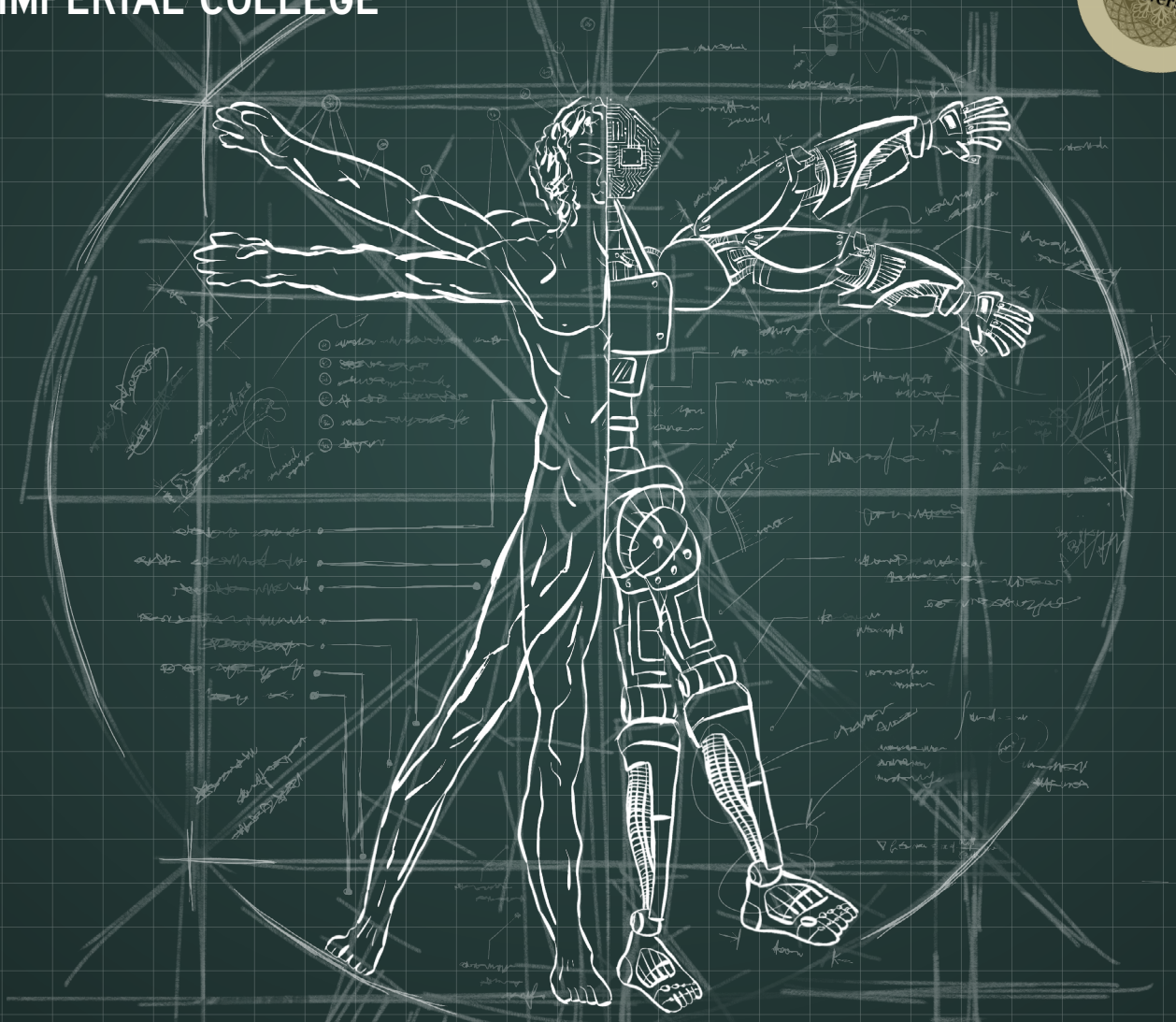
I, SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

10th Anniversary



WHO ARE WE?

SPRING 2015

I,SCIENCE

THE SCIENCE MAGAZINE OF IMPERIAL COLLEGE

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I,SCIENCE

10th Anniversary

10 years. 30 issues. 1,000 website posts.

This is who *I, Science* is. A decade on from its first publication on 14th March 2005, we are pleased to be the editors of this special anniversary edition asking the question: Who are we?

Since it's our birthday, we have an interview with Darius Nikbin, the first Editor in Chief of *I, Science* on pages 20-21, which discusses the founding ideals of the magazine, his thoughts on its growth in the last ten years, and where the future may take us.

Introspective examination aside, in this issue you will also discover exactly who you are and what makes you tick. This includes a look on page 10 at the organs you may have forgotten existed all together.

We consider the origins of *Homo sapiens* on page 6, discussing the evolutionary process from our long dead ancestors and how modern humans adapted to changes in their environment. Similarly, page 22 explores the origins of biological life itself, and how we all came from the stars to inhabit the earth.

On page 15 you'll find answers to a question asked often within the realm of science fiction about what we could become: if humans upload their consciousness into a computer? We also investigate whether it is our memories that make us who we are (page 19), or if morality is the keystone to our humanity (page 25).

We hope you enjoy our 10th anniversary issue and learn a little bit more about who you are. ■

JENNIFER AND IONA

FIND MORE GREAT CONTENT ON OUR WEBSITE: WWW.ISCIENCEMAG.CO.UK

We're always on the lookout for potential new contributors for both the magazine and the website.

If you are interested and would like to get involved as a writer, editor or illustrator please don't hesitate to get in contact. You can email us at i.science@imperial.ac.uk, tweet us @i_science_mag or contact us directly through our website www.isciencemag.co.uk.

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THE MOON MAY PROVIDE INSIGHTS INTO THE ORGANIC EVOLUTION OF THE EARLY SOLAR SYSTEM

CHARLOTTE MYKURA

The Department of Earth Science and Engineering at Imperial College has found that sampling the dark, basaltic plains of our Moon may reveal the organic matter present in our early solar system.

Between 4.2 and 3.7 billion years ago, the inner solar system underwent an intense bombardment of asteroids. Previous analysis of meteorites indicates that this bombardment both generated organic compounds and delivered them to planetary surfaces. Some of these compounds, such as amino acids, nucleo-bases and carboxylic acids are the building blocks of life.

Records of Earth's organic chemistry before 3.8 billion years ago has been completely obliterated by violent volcanic activity and movement of tectonic plates, which generated so much heat and pressure that all of Earth's oldest rocks have been severely altered. These alterations make it impossible to interpret the ancient terrestrial environment using material from Earth.

In order to understand the conditions that gave rise to the life-generating capacity of Earth, we require a record of the materials that were circulating and impacting Earth during the early phases of land, ocean and atmosphere formation. During this early period, the moon would have been subject to the same delivery of organic compounds as Earth. Thus an archive of organic material could remain buried in the loose, heterogeneous dust and rock covering the moon, intercalated with larva flows from the early lunar volcanoes.

This study, published in *Astrobiology*, simulated the lunar environment 3.8 billion years ago. A synthetic material that resembles rocky dust from the moon (modelled on lunar samples such as those brought back by Apollo 11) was studied in response to the effects of heating by overlying lava flows. The experiment demonstrated that early lunar conditions appeared to promote polymerisation of organic molecules, thus allowing them to be stable enough to persist on the moon for us to study them, billions of years later.

These findings reveal the lunar conditions that would have allowed the preservation of early organic molecules in the solar system. Analysing material from the moon will therefore facilitate understanding of the early conditions present in our solar system just before life first formed. ■

Charlotte Mykura is a second year PhD student studying epigenetics

METAMATERIALS WITH "PEN AND INK"

ANDREW MCMAHON

Researchers in the Department of Physics and Centre for Plastic Electronics at Imperial have developed a new type of 'metamaterial' which uses changes in a molecule's geometry to change the frequency and direction of the light it emits. The molecules were effectively drawn onto a substrate using a method called 'dip-pen nanolithography' and could change the way scientists design and develop optical materials for technological use.

This new feat of metamaterial engineering, described in *Nature Communications*, allows researchers to deposit certain types of organic polymer (long chains of repeating molecular units) on a substrate using the 'dip-pen' technique. This causes changes in the shape of the polymer that allows new control over its optical properties.

A metamaterial is a material that has been designed to have properties that would not usually be found in nature, usually through the use of geometrical structures that are larger than atoms but still microscopic. Optical metamaterials are perhaps the most famous of these materials, mainly due to Imperial College's metamaterial-based 'invisibility cloak', the theory of which was developed by Professor John Pendry in the Department of Physics.

The 'dip-pen nanolithography' deposition technique works by coating what is essentially an atomically thin pen tip with a solvent, which in this case swells upon contact with the substrate. This swelling induces a change in the geometrical conformation of the polymer such that adjacent molecular segments are essentially pointing in different directions. This is what gives the optical properties of the deposited film directional dependence. Control of this directional dependence may one day lead to LED sources that emit light in a tightly controlled direction as opposed to at many different angles.

It is also hoped that such detailed control over optical properties may find application in other technologies as diverse as optical waveguides, lasers or output and input couplers for photonic devices. ■

Andrew McMahon is a first year PhD student studying physics.

TROPICAL ANT COMMUNITY STRUCTURE UNVEILED

MADELEINE HURRY

Ants are more likely to fight with colonies similar in body size than with colonies of larger or smaller body size. This rule alone appears sufficient to explain the observed pattern of ant diversity in tropical fern-dwelling ants.

When two species inhabit the same area, they may compete for resources. This idea of competitive exclusion is prevalent in ecology, yet it is difficult to find empirical evidence to demonstrate the link between individual competition and overall community structure. Researchers from Imperial in collaboration with the Natural History Museum, University of Cambridge and Universiti Malaysia Sabah have explored this concept using ant species.

The study looked at species composition of tropical ants inhabiting ferns in the forest canopy in Malaysian Borneo. With up to 12 ant species coexisting on a single plant, researchers tested whether size-based competition drove overall community structure. It was predicted that ants of a similar size have similar niches and therefore have greater competition for resources, and so will fight to out-compete each other.

The first part of the study involved observing and recording the ant communities on 86 bird's nest ferns in the Danum Valley Conservation Area in Sabah, Malaysia. They found that species whose body size differed by less than 13% were significantly less likely to live in close proximity.

Secondly, to see whether size-based competition was really driving this pattern, lab experiments in which resident colonies were threatened with invaders of either similar or dissimilar body size were carried out. They found that invaders were less likely to successfully occupy a fern when their body size was similar to the resident, due to increased aggressive defence by the resident colony.

Finally, a computer-based model was applied to test whether these size-based rules drive diversity. Simulations where ecologically similar species fought with invaders gave a final diversity outcome similar to the observed diversity in the natural environment. Thus, using the size-based rules allowed the model to successfully converge on a community similar to the natural one.

Therefore, simple rule-based interactions between individuals can have far-reaching consequences in the higher levels of community structure, potentially explaining the huge diversity of ants in the tropical forest canopy. ■

Madeleine Hurry is an MRes student studying experimental neuroscience.

CLASS OF ANTIBODIES AGAINST DENGUE FEVER DISCOVERED

NICOLE SAMUEL

A team at Imperial has discovered a new class of human antibodies against the dengue virus, which could be used in the development of a vaccine against this deadly disease.

Dengue fever is a mosquito-borne infection, caused by four subtypes of the dengue virus. Globally it is endemic in over 100 countries, with an estimated 390 million cases occurring each year. In most cases, dengue is a flu-like illness and is cleared by the body's immune system. However there is a risk of progression to a haemorrhagic fever – which can be fatal.

Currently there is no treatment and fighting the infection is left to the body's immune system. As part of the normal immune response, white blood cells produce specific antibodies that bind to parts of the invading virus and label them for destruction. Following recovery, the body retains the ability to produce these antibodies and the person becomes immune to reinfection. However, these antibodies are usually specific to one subtype and offer no immunity to infection by the other three. In fact people are at an increased risk of severe complications during subsequent infections.

The team at Imperial College studied antibodies produced following dengue infection and discovered a new class of antibody, which is effective against all four viral subtypes. These antibodies target a molecular bridge between two proteins that is common to all four virus types.

Excitingly these antibodies could be used in the treatment of dengue, or in the development of a new vaccine. This vaccine would contain this molecular bridge and would stimulate the immune system to produce antibodies against it. The immune system would then be able to recognise and neutralise any dengue virus.

The incidence of dengue is climbing rapidly, despite all efforts to contain it. 40% of the world's population live in endemic areas and risk multiple dengue infections and severe complications. While there are vaccines being trialled, none of them offer full protection. The hope is that this discovery can offer a new approach to treat infection by all dengue subtypes. ■

Nicole Samuel is a fifth year medical student.

THE RISE OF HOMO SAPIENS

From the origin of life through to the development of language and culture, Charlotte Mykura explores the rise of human beings.

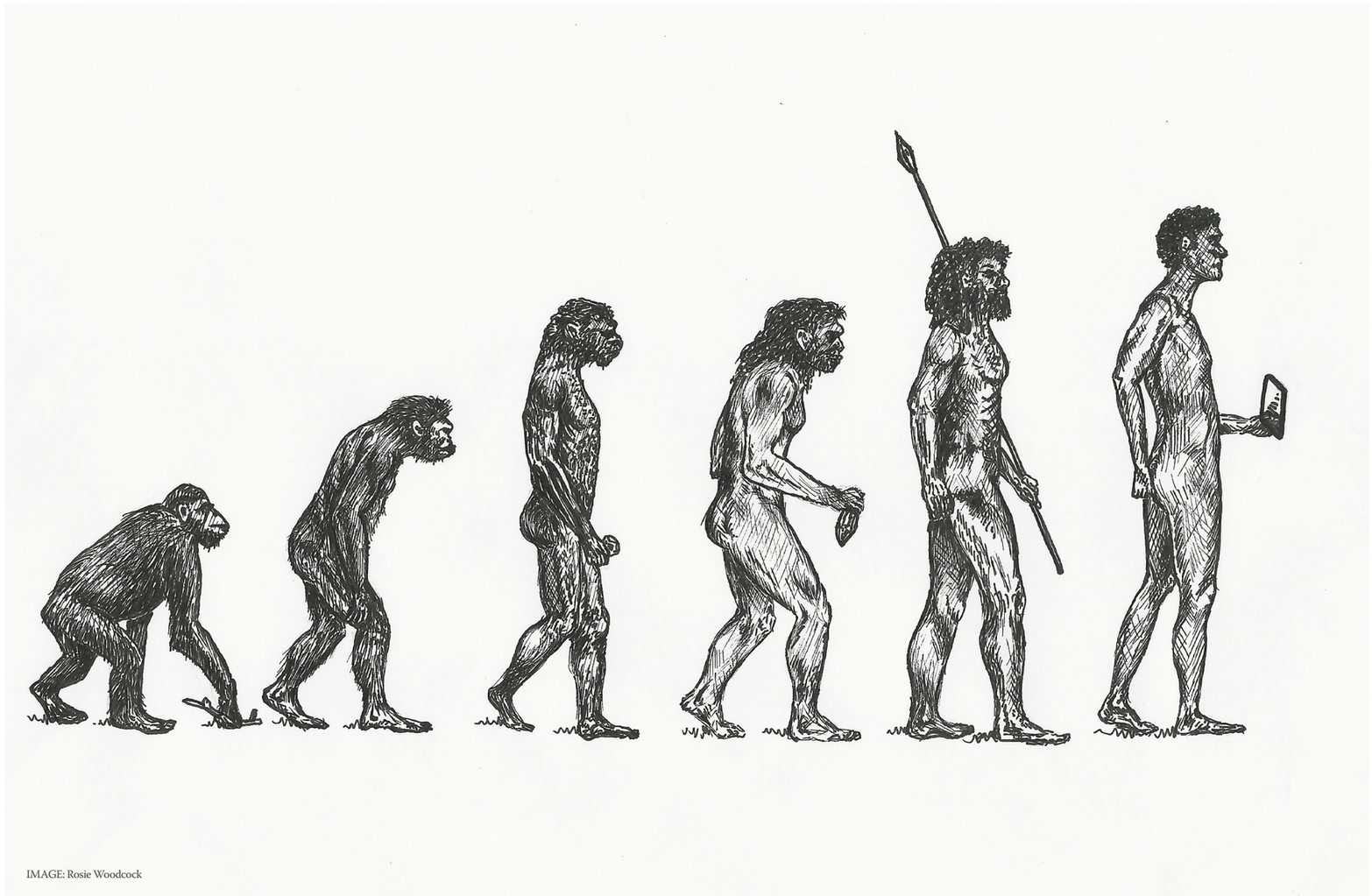

IMAGE: Rosie Woodcock

AN EVOLUTIONARY PERSPECTIVE: WHO ARE WE?

Of the millions of species that have ever existed on this planet, humans have singled themselves out as special. It isn't our bizarre appearance, with our enormous heads, strange bipedal skeletons and bald physique, that immediately strikes us as our most success-endowing quality. Rather it is our immense cultural diversity. This has allowed us to accumulate a collective knowledge that gives us the quality of a single super organism.

But if you take a step back to understand the 3.5 billion year story of evolution via natural selection that has given rise to you, you may well reach a greater appreciation of who we are.

> IF YOU TAKE A STEP BACK, YOU MAY WELL REACH A GREATER APPRECIATION OF WHO WE ARE

FROM HUMBLE ORIGINS: RNA WORLD

Life began in the form of a simple self-replicating RNA (ribonucleic acid) based molecule. The nucleic acids acquired a fatty bubble-like membrane to protect themselves, as well as coding properties and a simple energy metabolism which enabled them to thrive. Thus cellular life was born.

Later, RNA was switched for its less reactive little sister, DNA (deoxyribonucleic acid). DNA is almost exactly the same as RNA, except it is missing an oxygen atom from the ribose group.

Today there are three domains of life present on this planet. Around 3.5 billion years ago bacteria were present, followed half a billion years later by another domain of life, archea. Another billion years down the line, eukaryotes were born. Whilst bacteria and archea were to remain forever microscopic, eukaryotes evolved the capability to stick together and form large multicellular organisms such as plants and animals. We owe our existence to the humble origins of our eukaryotic ancestors.

STANDING ON TWO FEET

Granted, between the origin of eukaryotes and the existence of primates, a lot of evolution happened. But now we will fast forward into the African wild of our ancestors.

Between four and seven million years ago our ancestors, of the *Australopithecus* genus, did something amazing. They stood up on two feet. The previously quadrupedal (four-legged) ancestor underwent a myriad of skeletal and muscular changes over the course of millions of years to allow *Australopithecus* to become fully erect on two legs. The spine aligned itself underneath the head; the hallux (big toe) was recruited from its thumb-like past to become part

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EVOLUTION AND DISEASE

In life we are constantly aware of illness – from childhood colds to degenerative diseases of old age, it is constantly with us. A relatively new field – evolutionary medicine – attempts to uncover why we get sick by delving into the distant past. It explores how our evolutionary history can impact our susceptibility to disease and the way it manifests itself.

Evolutionary principles can explain many of the diseases in our society. For example cancer could be seen as a trade-off between the cell's capacity to repair and regenerate DNA and its propensity for mutation in later life. Metabolic syndromes (including diabetes and heart disease) could be due to a mismatch between our current sedentary lifestyles and diet and the hunter-gatherer lives of our ancestors. Short-sightedness has been linked to abnormal development in the eye because children spend too much time indoors, compared with ancestral populations where constant exposure to bright sunlight was the norm.

The list of examples stretches on. What becomes clear is that disease is as much a part of who we are as is our ability to walk on two legs or to speak a language. It has been there throughout all of our evolutionary history. ■

Nicole Samuel, Medicine, fifth year

See a full version of the article online at www.isciencemag.co.uk

of a foot used only for walking and no longer for grasping branches. Unlike our chimpanzee-like relatives, the pelvis became bowl-shaped rather than elongated. As our legs became more substantial, we lost muscle mass from our arms and our rib-cage became slimmer and less barrel-shaped.

Bipedalism gave our ancestors the freedom to use their hands. No longer required for walking, hands could now make tools, carry young or game, gesture and hold hands. Thus walking on two legs allowed our mental and cultural evolutionary acceleration. Although *Australopithecus* was much smaller, much hairier with a lesser brain capacity and more restricted diet than the later genus *Homo*, it already had modern hands.

Two types of *Australopithecus* were present (sometimes referred to as different genera); the robust and the gracile. Robust australopithecines were much bulkier, with teeth geared for breaking down plant material. It was the smaller gracile lineage, with a more varied diet and greater aptitude for coping with a fluctuating environment that would eventually give rise to the *Homo* lineage.

EATING OUR WAY UP

The extant hominids, which include apes and humans, come from a strongly plant eating ancestry. Early hominids lived in a woodland-savannah environment in Africa and ate only ripe fruits and other high quality plant sources. So how did our varied diet come about? When the environment became increasingly open and dry 2.5 million years ago, high quality plant materials became difficult to source. Of the early hominids, robust australopithecines turned to lower quality plant food. The gracile australopithecines managed to acquire the same quality of food as before.

However, *Homo* turned to animal source foods (ASFs). ASFs hold a significantly higher amount of nutrients and vitamins than the same amount of plant materials, which are crucial in the development of the brain. With increasing cranial capacity and use of stone tools, early *Homo* individuals were able to hunt animals for food, which further increased their intake of ASFs. Harsh conditions and severe competition for limited terrestrial food source continued, so *Homo sapiens* turned to freshwater and shell fish which provided polyunsaturated fatty acid. This is vital for brain development and makes our brain the most complex of all *Homo* brains. ■

Yung Nam Cheah, MSci Geology, fourth year

See a full version of the article online at www.isciencemag.co.uk

OUT OF AFRICA

During the Pleistocene epoch around 1.8 million years ago, our planet was subject to a series of climatic shifts with repeated glaciations. *Homo ergaster*, a large, sturdy fully bipedal ape with short arms, was roaming across Africa and Europe.

Then, between 800 and 500 thousand years ago, a more intelligent ape emerged from *Homo ergaster*: *Homo heidelbergensis*. This ape had a very large brain with a rounded cranial vault and used highly specialised projectile weapons such as wooden spears to hunt. *Homo heidelbergensis* gave rise to two new species, *Homo neanderthalensis* in Europe and *Homo sapiens* in Africa.

Between 900 and 300 thousand years ago, warmer periods swept across African and Eurasia, replacing desert with grasslands and the North African herds were able to move back and forth into Eurasia with the seasons. It is thought that *Homo sapiens*, anatomically modern humans, followed these herds for meat, and by 120 thousand years ago, tribes of individuals had left Africa for good.

Homo sapiens spread across Eurasia. Some of our ancestors followed the southern coastline down into India and across Asia, eventually reaching Australia by boats. Others were able to cross an ice sheet from Russia into Alaska, thus populating the Americas.

Today, the most diverse human populations (both genetically and anatomically) reside in Africa. As you move away from Africa, genetic diversity becomes more and more reduced. This pattern did not occur by chance; it demonstrates the pattern of migration taken by our ancestors. It was only a small group of African humans, a thousand or so, that left Africa to populate all four corners of the globe.

THE ONLY HOMININ

Archaeology tells us that the Neanderthals were pushed further and further into Western Europe, disappearing altogether around 29 thousand years ago. Whether this extinction was due to conflict with *Homo sapiens*, competition or changes in climate is a topic of fierce debate among evolutionary biologists.

Curiously, sequencing of the Neanderthal genome in 2010 taught us that 1-4% of non-African human DNA has Neanderthal origin. No humans of pure African descent contain Neanderthal DNA, since their ancestors never came into contact with Neanderthals (who are thought to have exclusively populated Eurasia). At some point in our history, *Homo sapiens* and *Homo neanderthalensis* interbred in Europe.

LANGUAGE, ART, CULTURE

What set us apart from our hominin relatives? They were just as fast and as strong as us and in some cases even had larger brains.

For example, the gene *FOXP2*, thought to have arisen between 200 and 50 thousand years ago in the human lineage, allows fine motor and neural control of the mouth and tongue; allowing the existence of complex speech.

Humans brought with them an immense toolkit to Europe; cave art, figurines, symbolism, language, religion. There was no one point when humans become modern, but a gradient of cultural evolution that started within Africa 300 thousand years ago put us in greater stead to outcompete our *Homo* counterparts in a changing environment.

Between 8,500 and 2,500 years ago, humans started abandoning their hunter-gatherer way of life for one in which they had fixed homes and farmed the land: thus society was born.

> **“UNLIKE OUR CHIMPANZEE-LIKE RELATIVES, THE PELVIS BECAME BOWL-SHAPED RATHER THAN ELONGATED.”**

HOMO SAPIENS: WHERE NEXT?

As directional natural selection is relaxed since our cumulative culture provides entirely for our needs, we have lost the drive to retain the ability to survive in a harsh environment.

As we more and more extensively define our artificial environment, we adapt to that environment which our recent ancestors have created. So where next? Will *Homo sapiens* reach a greater level of collective intelligence, save their planet and learn to thrive? Or consume resources to their ultimate demise? Only time will tell. ■

Charlotte Mykura is a second year PhD student studying epigenetics

FORGOTTEN ORGANS

Joanna Blackburn shines light on important but often forgotten organs of the human body.

WHY IS THE THYMUS ESSENTIAL TO MY HEALTH?

The thymus gland is located between your lungs and it produces the hormone thymosin. Thymosin stimulates the development of white blood cells, also called lymphocytes, into T lymphocytes. These T lymphocytes are crucial in fighting disease through the adaptive immune response. Removing the thymus during infancy can have serious immune consequences. However, removal after childhood has little effect. This is because after puberty, the thymus begins shrinking and this continues for the rest of your life. This shrinkage may be one reason why the immune systems of elderly people are less robust than those of younger individuals.

WHAT ARE THE ADVANTAGES OF HAVING ADRENAL GLANDS?

Situated on top of the kidneys, the adrenal glands secrete four main hormones. First, they produce cortisol and aldosterone that help regulate metabolism and control blood pressure respectively. While these functions are crucial to life, it is the adrenal glands' production of non-essential hormones, such as adrenaline and noradrenaline, which is better known. These help your body respond to stress as part of the fight or flight response. Adrenaline is particularly important in this process as it increases the heart rate and blood sugar levels.

DO I NEED MY APPENDIX?

The appendix is a thin tube around four inches long found between the small and large intestines. The appendix is a vestigial structure, which means it has lost most of its original function. Therefore, it can be removed without long-term consequences and is often removed in cases of appendicitis. It is thought to have had a role in plant digestion, which has since been lost. There is a growing body of thought that the appendix may have an important role in maintaining gut flora. This theory posits that the appendix acts as a storehouse for good bacteria that can replace stores lost due to diarrhoea.

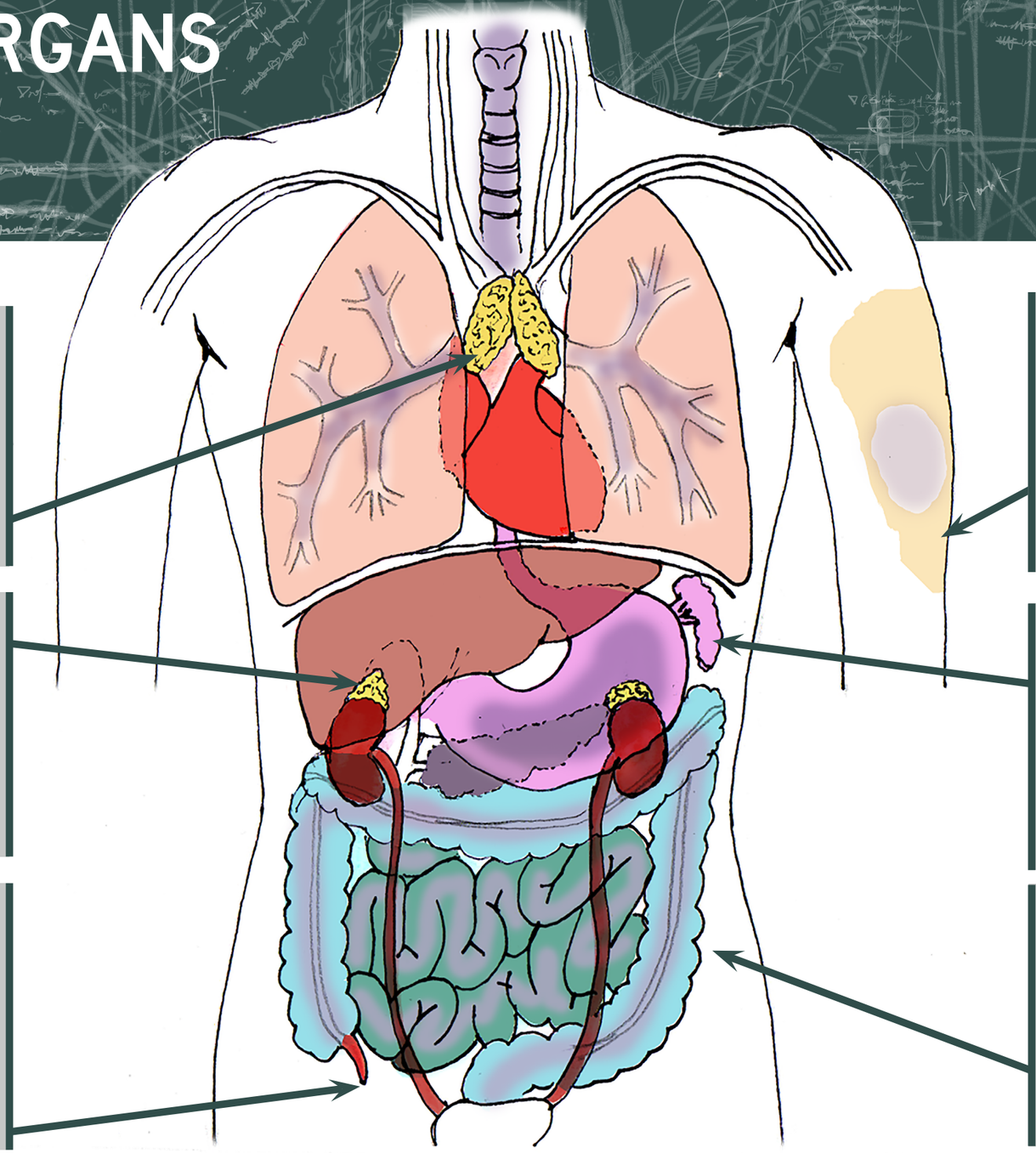

IMAGE: Kate Whittington

WHY IS MY SKIN SPECIAL?

The skin is the largest organ of the human body and it accounts for around 16% of our body weight. Skin serves several functions including protection from microbes, regulation of body temperature and enabling the sensations of touch, heat and cold. The outer layer of skin, called the epidermis, is replaced around every 30 days by the deepest layer of epidermis that is made of constantly dividing cells. The inner dermis, made of collagen and elastic fibres, contains touch, pressure and pain receptors along with hair follicles and sweat and oil glands. It is the decreasing number of collagen and elastic fibres as we age that causes wrinkles. Melanin-producing cells called melanocytes determine skin colour by producing a protein called melanin.

WHAT DOES MY SPLEEN DO?

Your spleen is primarily a blood filter. Blood first enters the white pulp where immune cells screen the blood for disease-causing microorganisms, called pathogens. A subtype of immune cells called T cells recognise invading pathogens while a second type, called B cells, make antibodies which can then help to fight off an infection. Subsequently, blood enters the red pulp. Here old red blood cells are removed and platelets, which are involved in blood clotting, are stored. In addition, before birth the spleen can also produce new red blood-cells. In spite of the spleen's importance it is not actually vital for life; however people without a spleen may be more prone to infection.

WHAT IS THE IMPORTANCE OF MY MICROBIOME?

A microbiome consists of all the microorganisms that live within us.. These microbes outnumber our own human cells by 10 to 1. We have a particularly important relationship with our gut microbiome. Found in our intestines, the gut microbiome has many important functions including food digestion and forming a barrier that protects against enemy microorganisms as part of the immune system. They also produce the vitamins B and K. About two-thirds of this gut microbiome is common to all humans with the remaining one-third unique to individuals. In particular, the microbiome is found in those areas highlighted in purple. ■

Joanna Blackburn is studying for an MSc in Science Communication.

CHANGING OURSELVES

From hammerstones to biotechnology, Lizzie Norris looks at the engineering that has helped us to increase our lifespan and improve our quality of life.

The last 2.6 million years have seen the breadth of human engineering and invention. From ancient humans using hammerstones to hunt animals to modern day biotechnology and complex drug delivery systems, we have used engineering to change ourselves and the world around us.

Engineering is fuelled by an immediate need to solve problems and improve our environment. Many of the greatest lifesaving engineering developments are simple and low tech. Take the seat belt for example or the LifeStraw, a recent award winning innovation which is used to purify water for those living in developing countries.

However good engineering is not easy; many of the simple inventions in use today are examples of bad engineering. Luer (Tubing and Catheter) misconnections are examples of this. Misconnections allow gasses and liquids to enter the wrong lines in patients, while bad catheter insertion can also cause problems with pressure build up when inside the body causing tearing and tissue damage.

What is good engineering and how have we used it to improve ourselves? The last few hundred years have seen many innovations which have increased our lifespan. It is difficult to pinpoint specific solutions that have done this but vaccinations and the invention of antibiotics are a good place to start. The smallpox vaccine is credited with saving the lives of approximately 530 million people worldwide, whilst the measles vaccine has saved an estimated 118 million lives. The development and large-scale deployment of antibiotic drugs has saved around 82 million lives.

Access to clean water and sanitation have also had a considerable impact on our way of life. How many lives has the invention of the sewer system saved? What about the role of soap in preventing the spread of germs? Could soap be credited as being one of the most fundamentally important inventions? We could speculate forever.

> **“COULD SOAP BE CREDITED AS BEING ONE OF THE MOST FUNDAMENTALLY IMPORTANT INVENTIONS?”**

Life expectancy statistics are useful when considering these questions. However they are often skewed by factors such as high infant mortality rate and may not represent the age most adults lived to. Statistics from the 1700s show that while the average life expectancy at birth was 25-40 years, if you survived childhood, your life expectancy might increase significantly beyond the ‘at birth’ expectancy. So how have we reduced infant mortality rates?

Low birth weight (LBW) is a primary cause of infant mortality. In developing countries this accounts for 60-80% of infant deaths. The rate is increased by the young age of mothers, poor nutrition, air pollution, and drug and alcohol abuse.

The World Health Organisation estimates that indoor air pollution causes more than 1.6 million premature deaths yearly, the majority of these in children under five. More than half of the world’s population use open fires or traditional biomass stoves to cook. Household members, particularly women and children, are exposed to smoke and, by extension, to high risk of death or illness from respiratory problems.

So how have people attempted to counter this problem? While the Romans used tubes inside the walls of bakeries to draw smoke out, chimneys only appeared in dwellings in Northern Europe in the 12th century. They were engineered as a solution to reduce the build-up of smoke in the home, but the long-term health problems associated with smoke inhalation have only recently become well understood.

Despite this knowledge, in many communities today fuel supplies are limited, so anything from kindling to dung is burned for cooking and heating. The architecture of many dwellings often makes chimneys or fume extraction impossible. There are many organisations working to produce cleaner stoves and to encourage the use of cleaner fuels.

Under-nourishment and starvation also significantly contribute to LBW and premature death. History is littered with periods of famine all over the world. However, history also yields examples of innovative solutions to some of the key drivers of famine. For instance, rapid population increase in the 1800s meant that farmers struggled to produce enough nitrogen from manure to fertilise farmland. Scientists were unable to synthesise nitrogen until the early 1900s, when Haber and Bosch produced an industrially viable solution. In his book, ‘Enriching the Earth,’ University of Manitoba Professor Vaclav Smil calculated that over 2 billion people, just under 40% of those alive at the turn of last century, were fed by food grown using the Haber-Bosch process, demonstrating that discovery and invention continue to form the very basis of the way we live our lives today.

Identifying the inventions of today that will have the biggest impact on our lives is difficult, as lone feats of engineering rarely improve the lives of many. It is the cumulative effect of many different minds, components and refinements over time that produce strong solutions which lead to a significant impact on our lives. ■

Lizzie Norris is studying for a PhD in Advanced Characterisation of Materials

IMAGE: Wikimedia Commons/Kunda Culture Tools

BIONIC IMPLANTS:

WHAT ARE THE LATEST TECHNOLOGIES HUMANS ARE USING TO CHANGE THEMSELVES?

COCHLEAR IMPLANTS

Gene therapy has the potential to improve the interaction between human tissue and bioimplants. By delivering gene therapy to the inner ear, underdeveloped or damaged auditory nerves could be encouraged to regrow. The theory is that as a result, the implant will work more similarly to the human ear and provide the user with a more natural sound.

ARTIFICIAL PHOTORECEPTORS

Researchers from Stanford University, California, believe photovoltaic arrays of pixels may just be the answer to curing blindness. By inserting electrodes between the retina and the retinal pigment epithelium, a thin layer of cells, the electrodes stimulate the inner retinal neurons. This allows them to transmit signals to the brain while preserving the body’s natural signal processing network.

BIONIC LIMBS

Scientists are currently developing ways to connect prosthetic arms and hands to the nervous system. The hope is that this will result in even greater control of bionic arms by allowing the brain to directly control their movements, much like it does with natural limbs. Bioengineers can either connect the limbs directly to the central nervous system (brain and spinal cord) or to the peripheral nervous system (nerves that connect the extremities with the brain and spine).

3D PRINTING

Using 3D printing, scientists have been able to create intricate scaffolds that mimic structures in the human body. This technique allows the growth of tissues for implantation, letting doctors and scientists make scaffolds that are created specifically for the task at hand. It is hoped that this specificity will increase biocompatibility and result in the recipient receiving an implant that feels almost completely natural to them.

BIOACTIVE GLASS

Many bone injuries are complex and difficult to repair using existing methods. However, bioactive silica fibre structures encourage the growth of bone tissue and researchers have recently developed a technique allowing them to create very flexible, cotton-candy-like silica structures that can be packed into damaged areas to stimulate healing. Whilst reserved for areas of the body that do not bear much weight, this technique would nonetheless simplify treatment by allowing a surgeon or dentist to simply ‘push’ the material into the affected area. ■

Arutyun Arutyunyan, MSc Advanced Materials Science and Engineering

MEMORY MAKETH MAN

Eleanor Magson investigates whether memories make us who we are.

IMAGE: Sadhira Wagiswara/Henry Molaison

In 1953, Henry Molaison left an operating theatre in Connecticut and became one of neurology's most renowned case studies: H.M. In August of 1953, at the time of H.M.'s surgery, President Eisenhower was in the White House. But in Molaison's mind, he never left.

Molaison's operation was an attempt to cure intractable epilepsy which he had suffered from since childhood. His doctor believed the brain regions responsible for the seizures were the medial temporal lobes – and suggested a surgical removal. This is a practice that continues today, although a great deal more attention is given to the possible implications of removing areas of brain tissue. When Molaison had his surgery, little was known about functional specialisation of the brain – or the idea that different functions of the brain were localised in different brain regions.

Unfortunately, although the surgery was successful in its primary aim of curing Henry's epilepsy, it left him with severe memory damage. Molaison had anterograde amnesia – he was unable to form new memories. Molaison could still remember events and information learned prior to his surgery, such as childhood memories. Learning new information, however, became impossible. Molaison still believed he was living in 1953 up until his death in 2008. He could neither retain new information, nor remember his own experiences from after the surgery.

It became clear that the removal of the temporal lobes was responsible. Molaison's case helped to prove that temporal lobe structures, including the hippocampus and entorhinal cortex, play a key part in forming and retaining memories.

After Molaison's surgery, he became the focus of scientific study and fascination. Studies performed on him from the late 50s until his death showed that Molaison had functional working (short-term) memory. His procedural memory was also intact – he could learn new motor skills with ease, despite not remembering learning to do them. This suggested that these types of memory are controlled by areas of the brain not affected by his surgery, leading the way for a more nuanced understanding of the many functions of what we term 'memory.'

> **“WHETHER MEMORIES ARE LOCALISED IN ONE BRAIN REGION OR ACROSS MANY, MEMORIES, CONTAINED WITHIN NEURONS, HOLD OUR EXPERIENCES OF LIFE.”**

Unable to convert short-term memories into long-term ones, Molaison lived his life completely in the present. Suzanne Corkin, a researcher who spent years of her career working with Molaison, described him as an 'engaging, docile man, with a keen sense of humour.' Although his lack of self-knowledge, and moment-to-moment existence makes it difficult to comprehend, Molaison retained his personality. He had the same manner, the same likes and dislikes, and the same sense of humour. This is perhaps much down to the type of memory loss Molaison suffered. While he remained 'frozen in time' at the age of 27 in a never-ending 1953, his retention of memories helped him to stay, in the minds of others as much as his own, the same person.

The same, sadly, cannot be said for those suffering from diseases such as Alzheimer's. Memory loss is an early and major symptom of this kind of dementia, and modern histological techniques have shown that the brain regions first affected by the disease are the very same which H.M. had removed. As well as memory loss, Alzheimer's is a degenerative disease which later affects the whole brain, leading to personality changes, which are thought to be localised in the frontal areas of the brain. Although symptoms and experiences of Alzheimer's are varied, many patients lose memories of their life which render them, to family and friends, as no longer the same person. One daughter of a parent with Alzheimer's says 'I feel as though I lost my mum a long time ago… she became a different person.'

Today, we know broadly which functions are performed by different areas of the brain (partly thanks to patients like H.M.), but trends in neuroscience have changed, with many researchers now looking at the interconnectedness of brain regions. Whether memories are localised in one brain region or across many, memories, contained within neurons, hold our experiences of life. Perhaps it is these intricacies of a fully lived existence which accumulate to make us who we are. ■

Eleanor Magson is studying for an MSc in Science Communication

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SCIENCE BEHIND THE PHOTO: FIBONACCI NUMBERS

Photo and words by Yodit Feseha

When we look at the bud of a rose, we see a striking example of a mathematical phenomenon found throughout nature, including in humans.

Born in the late 12th century, the mathematician Leonardo Fibonacci discovered the Fibonacci sequence and its surprising presence in nature. The Fibonacci sequence is a sequence of numbers in which the next number is found by adding the two numbers prior to it together. It starts: 0,1,1,2,3,5,8,13,21,34,55… Subsequently, dividing the larger number by the previous smaller number in the Fibonacci sequence always gives a number known as the golden ratio (φ), which is approximately equal to 1.618. The squares of sequential numbers in the Fibonacci sequence also tend to form a spiral shape which is seen throughout nature, for example in sea shells.

The Fibonacci sequence is also seen in rose petals. The average arc of the circle these petals follow during growth is 137.5˚, the golden angle. This arrangement is very efficient for the rose: as the petals grow out it allows the smaller ones to get sunlight, giving the rose even exposure to the sun throughout development.

Our bodies too are a prime example. The Fibonacci spirals can be seen in our ears, cowlicks, the shape of the human embryos and fists. Even the DNA double helix and our facial dimensions are thought to follow the golden ratio.

Interestingly, the section of our index finger from the tip to base of our wrist is larger than the preceding one by about the golden ratio 1.618. We also have two hands, each with five digits, and our eight fingers are each comprised of three sections: all Fibonacci numbers! ■

Yodit Feseha is studying for an MSc in Human Molecular Genetics

THE REAL X-MEN

Bentley Crudgington examines how X-ray crystallography has allowed us to understand what we really are.

If you want to answer the question 'who are we?' you might first need to ask the question 'what are we?' Answering that would almost certainly require X-ray crystallography.

Most people are familiar with an X-ray and its basic principles; X-rays pass through materials at different intensities to produce light and shadows on a film. X-ray crystallography is similar, except that the shadows it casts create a complex puzzle that, when it was first used, fundamentally changed the way we looked the physical world.

In 1914 Max von Laue, a German physicist, won a Nobel Prize for demonstrating the diffraction of X-rays by crystals. These diffraction patterns, resembling astrological charts drawn in Morse code, became a pre-war magic eye puzzle with scientists all over the world trying to link these speckled patterns to determine the atomic structure of the crystals in question.

It took the father-and-son team of Sir Henry Lawrence and William Lawrence Bragg to solve it. William looked at the problem in a new way by thinking about the structure of the material itself rather than the behaviour of the X-rays. William proposed that crystals were arranged in highly organised repeating sheets, stacked one on top of the other, a set distance apart. With the assumption that each of these sheets would act as an imperfect mirror, and X-rays bouncing off lower mirrors would interfere with the X-rays bouncing off higher mirrors in a predicable way, they formulated Bragg's law. It was deceptively simple but at last showed the existence of atomic particles.

What this law demonstrates is that if you want to find out how atoms are arranged in a particular material, it helps to have a lot of them in a very uniform arrangement. This is why crystallised structures are used. The high energy and small wavelength of X-rays make them ideal to fire at crystals. Exactly how X-rays deviate from

IMAGE: Kate Whittington

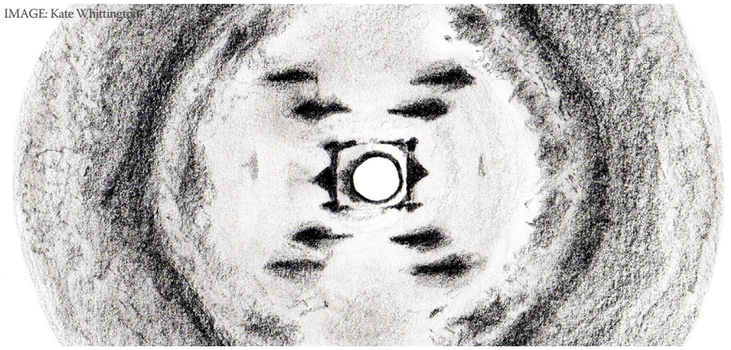


Photo 51, showing x-ray diffraction pattern of DNA

a predicted path is directly linked to the size and position of the atoms they encounter. Bragg's law helped scientists to calculate the number, size and relative position of atoms in a material, turning 2D patterns into 3D structural models.

The Braggs were awarded a Nobel Prize in 1915 and at 25 years old William was the youngest ever recipient. He received the news while fighting in the trenches of World War I where things were far from sterile and organised. But the Nobel legacy does not end there.

After the war, William set up a crystallography group at the Royal Institute. It was there that Kathleen Lonsdale used X-ray crystallography to answer the biggest question in analytical chemistry at the time: the configuration of the benzene ring, a type of molecule made up of carbon atoms arranged in a ring. Her approach continues to underpin the analysis of such structures, collectively termed aromatic molecules, to this day.

In 1945, Dorothy Hodgkin pioneered the field of protein crystallography, discovering the structure of penicillin, vitamin B12, and later insulin. John Kendrew and Max Perutz solved the structure of haemoglobin, the protein found in red blood cells and responsible for transporting oxygen around the body, in 1962. Three years later David Philips was able to use crystallography to work out how lysozyme, an antibiotic found in tears, worked.

But perhaps the most controversial discovery came earlier, in 1953, when Rosalind Franklin gave the now iconic photo 51 to a PhD student she was supervising to discuss with Maurice Wilkins. However, the image was shown without permission to James Watson. Watson and Francis Crick used data from the photo to help define the size and structure of DNA. In 1962 the Nobel Prize was awarded to Watson, Crick and Wilkins. Franklin, who had died four years previously, was not credited. It is hotly debated if Franklin would have solved the structure of DNA independently.

All told, nearly 30 Nobel prizes have been awarded to research using X-ray crystallography. It has profoundly influenced many scientific disciplines. From the structure of humble table salt to the design of new pharmaceutical drugs, X-ray crystallography has allowed us to understand what we are made of and how we work, and right now the Curiosity Rover is using it to find out where we may have come from. ■

Bentley Crudgington is a second year PhD student studying Virology

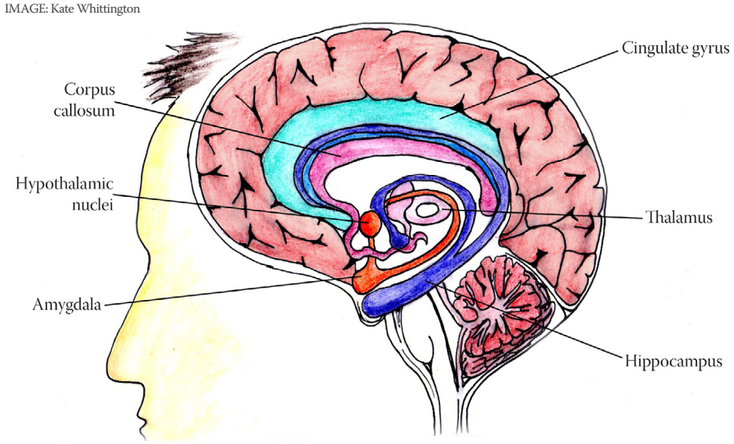
DECISIONS CAN BE COMPLICATED

Angelina Chrysanthou explores the sub-conscious factors which influence our decision making.

Decision-making is a continuous brain process that we are generally unaware off, until our choices result in unpredicted consequences. We may recall and wonder, 'Why did I choose that option? Was it conscious or subconscious? Was I emotionally influenced?' In recent years, neuroscientists have begun to decrypt our decision-making processes. What they are learning is shedding light not only on how a healthy brain performs complex mental functions, but also how disorders such as drug abuse can affect the process. Our decisions are what make us who we are, and the consequences of our decisions affect what happens throughout our lives and who we become.

A number of brain structures, including the anterior cingulate cortex, orbitofrontal cortex and the overlapping ventromedial prefrontal cortex are thought to be involved in decision-making processes. In these different brain regions, studies indicate that decisions result from rapid multifaceted probability calculations within the brains neurons.

IMAGE: Kate Whittington



It would not be unusual to imagine that successful decision making relies on the rational frontal lobes of the brain, and not from the emotional areas of the brain such as the limbic system which is found deeper in the brain. However, studies have shown emotions to aid in decision-making processes.

Decision-making often occurs in the face of uncertainty, situations when our choices will lead to benefit or harm. The emotional input provides the brain with motivation and meaning which are essential for effective decision-making. The limbic system, made up of the hypothalamus, the hippocampus and the amygdala (see diagram), is responsible for emotional responses. Studies have shown that people who have experienced damage to parts of their limbic system are no longer capable of making decisions, as their rational mind hesitates cyclically over the possible rational reasons for each course of action.

Conversely, people who experience damage on the rational frontal lobes of their brain were still capable of making decisions. Scientists from the University of Maryland monitored the micro patterns of activity in the frontopolar cortex of several participants. The results indicated they could predict each participant's decision up to seven seconds before the participant themselves became aware of their decision. Thus, humans typically make their decisions irrationally. However when a decision goes wrong and things don't turn out as predicted, the orbitofrontal cortex helps us change our behaviour by responding to our mistakes. This finding can also be linked to a study which found cocaine addicts who often exhibit damage to their orbitofrontal cortex, frequently not being able to weigh up the rewards of drug use against the costs.

Memory is another key factor of decision-making. The decisions we make are greatly influenced by our mood which works as 'a retrieval cue' whereby negative feelings make negative materials come to mind, which in turn have great impacts on the decisions we make. The same is true for positive feelings. In 1981, G. H. Bower termed this phenomenon 'state-dependent remembering.' Bower and his colleagues specified that feelings and emotions cannot be removed from the human mind. The emotions felt in specific circumstances will be recorded in the emotional memory, and can be triggered when a person faces a difficult decision over a short period of time. In these situations the decision-maker is usually unaware of previous experiences in similar past situations influencing their current situation.

The fact that most of our decisions and actions depend on 95% of brain activity beyond our conscious awareness, means that 95 – 99% of our life derives from the programming in our subconscious mind. Our subconscious controls what we do and who we are; now that really is something to think about. ■

Angelina Chrysanthou is studying for an MSc in Molecular Medicine.

ACHIEVING SINGULARITY

Tim Ellis examines how neuroimaging could lead to engineering an artificial human brain through advancing our understanding of consciousness.

The ability to process data can be separated into two broad categories, linear processing and parallel processing. The human brain is unrivalled in its ability to carry out parallel processing, giving us the unique ability to recognise patterns and compare courses of action in order to reach the most desirable outcome. However, when it comes to linear processing, the ability to rapidly carry out one task at a time, we are vastly out-performed by our technological progeny.

The responsibility of signal transmission within the brain lies with neurons, specialised brain cells that carry electrochemical transmissions. There are 86 billion neurons that make up the brain of an adult human, with approximately 100 trillion interneuron connections. As the brain fires millions of signals at any one time, signals that feed into neighbouring circuits, the human brain is 'massively parallel.'

Researchers attempting to map the brain and its trillions of connections are now able to use functional magnetic resonance imaging (fMRI) to track the firing of individual neurons through basic circuits. Increasing temporal and spatial resolution of brain imaging platforms, such as fMRI, will allow accurate tracking of concurrent neuronal firing through infinitely complex circuits. Being able to track multiple firing neurons simultaneously will allow us to map the massively parallel nature of the human brain.

Neuroimaging through fMRI enables researchers to map the structural changes within individual neurons, including the formation of new budding connections. Tracking these changes will allow us to further understand the dynamic nature of the brain and its synaptic plasticity, the process by which neurons form new connections, thought to lead to learnt behaviour and the formation of memories.

The evolution of the human brain may be beautiful in its depth of complexity and functionality, however the system is limited by the biochemical restraints of mammalian biology. The maximum speed of neural transmission is approximately 120 metres per second. If the theorised speeds of photon-based processing were realised in the future, neural transmission within the brain could be out-performed by a factor of three million.

The Chinese Tianhe-2 supercomputer is now capable of carrying out 33,860 trillion calculations per second, making it 41% more powerful than its American Titan predecessor. As the processing power of the average computer system increases exponentially every year, we will soon have the tools and processing power to identify every human neural connection and pathway. This will facilitate the creation of a reconstructed neuronal network, forming the basis of an artificial human brain.

Increased processing power, coupled with the development of parallel data processing from neurological research is theorised to lead to a point in which artificial computers will reach our 'unique' level of consciousness, and indeed surpass it. This point is referred to in the study of artificial intelligence as the 'Singularity.'

How will this vast expansion in artificial intelligence influence the world we live in? An entity that is capable of independent self-improvement will only become more intelligent at an exponential rate.

Topics of global importance including clean energy, personalised healthcare and global warming may indeed be resolved as nuclear fusion, nanotechnology and carbon fixing technology are optimised and perfected.

The application of this technology would be revolutionary in the running of our day-to-day lives, but where would it leave us? It has been suggested that the refinement of neuron networking technology in the future will enable us to record and upload our consciousness to online systems. Pre-existing communication networks, forming the basis of the modern day Internet, will allow the sharing and preservation of knowledge and memories. Could this harmony in technological power and biological creativity lead to intelligent transcendence and mental immortality? ■

Tim Ellis is a first year PhD student in Advanced Characterisation of Materials

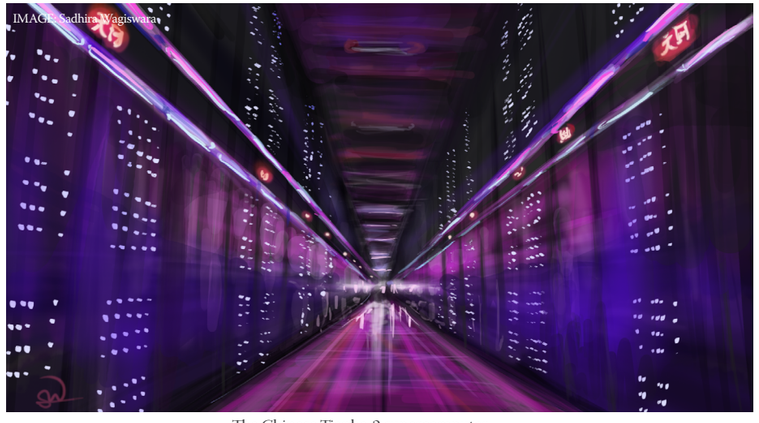


IMAGE: Sadhira Wagiswaran

The Chinese Tianhe-2 supercomputer

INTERVIEW WITH DARIUS NIKBIN


IMAGE: Kruti Shrotri

Darius Nikbin, the founder and first Editor-in-Chief of I,Science in 2005

To celebrate *I, Science's* 10th anniversary, current editors Iona Twaddell and Kruti Shrotri met up with Darius Nikbin, the founder of the magazine...

Did you imagine* I, Science *would be running 10 years after you founded it?
I thought that we'd run to about three, four, five issues, and then it would just peter out. I honestly didn't think it would be going for ten years, so I'm amazed. Every time I see *I, Science* still going on, I'm impressed, I think it's a great achievement.

What made you want to start* I,Science, *and how did you do it?
Initially it started with the science section in *Felix* newspaper. During my physics masters degree, I was amazed that there wasn't a science section of *Felix*, so I set one up. When I started doing the science communication course after my physics degree, I came up with this idea to have a science magazine at Imperial College run by students.

As soon as it became a reality in terms of the funding, we started thinking about what a science magazine would look like at Imperial College. We wanted to do something that was original, and, at the time, on a philosophical level, I was thinking about scientism - the view that there is an absolute truth and that science is the best means of approaching that truth - and post-modernism, which deals with relative truths. *I, Science* was born out of a kind of marriage between the two. And out of these two currents of thought we came up with a paradigm for *I, Science* and that was science in its social context. For me, science is a socially constructed phenomenon, but it's socially constructed based on observations of nature. So essentially we started working in this kind of intellectual space that we'd discovered.

***How did you come up with the name* I, Science?**
I came up with *I, Science* after having recently seen the science fiction film I, Robot at my uncle's house in New York, and the idea faced no opposition. I, Robot was, of course, based on the Isaac Asimov short story.

What are you doing now?
After I left Imperial College, I did a brief stint at the Times Higher and then I went to work at CERN for four months. And then I went to work at the Institute of Physics Publishing. After that I decided to do independent research with the view to getting a PhD and managed to start working on a new project in the field of Black Holes. Our aim is to get clean energy from black holes through a process called controlled black hole formation. It depends on a discovery of black holes at the LHC this year. So, if black holes are discovered in the LHC, what we envisage is that in a five to ten year timescale we build a new collider for the purpose of producing black holes in a controlled way. That's the aim.

Have you got a personal favourite science magazine (apart from* I, Science*!)?
Seed Magazine I'd say is my favourite. One of the difficulties I find with science magazines is that they don't really put scientists on the spot. When they interview a scientist there is an automatic assumption that they know more than you do; they elevate the person. I suppose I'd like to see, not just *I,Science*, but all science communicators really challenging the motivation of scientists – 'why are you doing this?' I think that *Seed Magazine* was fairly inspirational in that they did set out to promote science as an intellectual endeavour that isn't completely separate from other intellectual endeavours.

What is your best memory associated with* I, Science*?
I was working at CERN and heard that we were shortlisted for the Guardian Student Media Awards. We were quite chuffed that we'd been nominated because we'd only published two issues, and the minimum requirement was three issues. We went to the event and had a great time. And Russell Brand was there! He gave a talk, and wasn't too complimentary towards Imperial College! I remember meeting him afterwards down at the bar, and we had a brief conversation: And I just remember telling him what I thought of him and he told me what he thought of me! ■

IMAGE: Wikimedia Commons/Supernova Remnant

WE ARE STARDUST

Andrew McMahon discusses how the elements in our bodies came to be.

The human body consists of around 37.2 trillion cells, each made up of different kinds of molecules, and each containing several different types of atoms that are categorised into elements. These elements, built into molecules like DNA, RNA, enzymes, proteins, haemoglobin and others, constantly execute an array of processes within your body that keep you alive and functioning.

But where do all of these building blocks come from? The answer to this question may seem somewhat surprising. The simplest elements in the universe can be traced back to the Big Bang itself, but the majority of the elements inside our bodies can be traced back to processes that occur inside stars. We are all stardust.

STELLAR NUCLEOSYNTHESIS

Stars are huge thermonuclear power plants that release vast amounts of energy into space, mainly through the fusion of simple elements into heavier elements. For stars with a mass up to one and a half times that of our sun, the main process is the fusing of hydrogen to form helium. Energy released in this process counterbalances the effect of gravity such that as long as the star has hydrogen to burn, it does not collapse.

This process of nuclear fusion occurs in most stars over periods spanning billions of years. Our Sun has been burning hydrogen for around 4.5 billion years, and we estimate that it has about another 4.5 billion years of fuel left. Although the main nuclear reaction occurring in the star produces helium by fusing hydrogen atoms, sometimes the reaction goes further. In the core of stars with masses close to that of the Sun, helium atoms can fuse together to create beryllium, which can then fuse with helium to create carbon, the most important element for life on Earth. Heavier stars (more than eight times the mass of the sun) can create even heavier elements, such as the calcium and iron that are integral for your body to function.

> “THE MAJORITY OF THE ELEMENTS INSIDE OUR BODIES CAN BE TRACED BACK TO PROCESSES THAT OCCUR INSIDE STARS.”

STELLAR DEATH, TERRESTRIAL LIFE

As a star runs out of fuel and reaches the end of its life several things may happen, depending on its mass. If a star is large enough (about greater than three times the mass of the Sun), after it has used up its hydrogen fuel it begins fusing helium in a cooling, expanding outer shell. These ‘Red Supergiants’ continue burning for around a million years or so before instantly collapsing under their gravitational interactions. This collapse causes one final rebound due to energetic interactions within the core and the star explodes into a spectacular ‘supernova’, throwing elemental products out into interstellar space.

Smaller stars (of about the same mass as the sun) also expand as they use up their fuel. However, the end of their lives is a much tamer affair as they shed off their outer layers into a ‘planetary nebula’ – a cloud of dust that surrounds the core.

The dust that is left in the aftermath of stellar death contains a wide variety of elements, including those very heavy elements produced during the end stages of the star’s life. This interstellar debris then begins to collect under its own gravity: swirling, colliding and clumping together to create large pockets of gas which will eventually collapse under gravity to produce a new star. The heavier elements will similarly collect to produce rocky material and eventually form planets like the Earth. The elements that were created inside the star and expelled at the end of its life then reside throughout the planets formed. The majority of the time, these elements will have combined to form complex compounds, found as minerals in the Earth’s crust.

As life evolved on this planet, it used the raw materials in these compounds to build sophisticated biological systems. Fast forward approximately 4.5 billion years and you have the huge cornucopia of plant and animal life that we observe on Earth today, including ourselves.

So whenever you think of the origins of life on this planet, and think of the origin of the parts that make up your own body, remember that you should thank your lucky stars that you are here. Literally. ■

Andrew McMahon is a first year PhD student studying physics.

RULES OF ATTRACTION

Rachel David looks at what draws us together.

Your eyes meet across a crowded room. You know you are being obvious but you cannot stop staring. When you finally speak, butterflies flutter in your stomach. But what is it that makes that person so irresistible?

Cheesy romance aside, there is growing evidence that sexual attraction, a fundamental part of who we are, is governed by biology. Take looks for example; it seems obvious that we are attracted to others based on their physical appearance, even if we try and deny it. And although they say that beauty is in the eye of the beholder, there is support for the idea that we all look for certain qualities – symmetry, averageness and secondary sexual characteristics – that offer clues on potential benefits of choosing a person as a mate, either directly to us or to our potential offspring.

Yes, as boring as it sounds, average is what we actually look for, a face that resembles the majority of faces in a population and that lacks any extreme features. From a genetic point of view, averageness is thought to signal genetic diversity, a lack of potentially harmful genes (which may cause such extreme characteristics) and general health. Average faces also tend to be the most symmetrical, another feature we are attracted to as it also acts as a signal for health status and genetic fitness. Indeed, numerous studies have shown that digitally manipulating a face to make it more symmetrical is enough to increase its attractiveness.

There is also a link between attractiveness and the presence of secondary sexual characteristics: feminine female faces and masculine male faces. Once again, this is thought to be because such features 'advertise' the individual's reproductive health (for example, a strong jaw is a sign of high levels of testosterone) and genetic fitness.

Of course the story does not end with looks; our sense of smell is also thought to have a key role. In a classic study by Wedekind and colleagues, women were asked to rate the odour of T-shirts worn by male participants for two consecutive days. They found that the women were more attracted to the odour of men with MHC genes different to their own. These genes code for proteins that have a key role in the immune response, and so selecting a mate with a distinct set of genes would ensure diversity in the immune genes of their offspring. Although the exact role of MHC genes in mate selection remains controversial (another study found that women were attracted to the smell of men with MHC genes most similar to their fathers), it is clear that humans can discriminate at such a fine genetic level based on odour alone and use this information to help select a mate.

> **THERE IS GROWING EVIDENCE THAT SEXUAL ATTRACTION ... IS GOVERNED BY BIOLOGY**

Interestingly, hormones can also influence attraction, both at the level of visual and olfactory cues. For example, women tend to be more attracted to more masculine and symmetrical faces during ovulation, when they are at their most fertile. There is also some evidence that women in relationships with men sharing similar MHC genes are more likely to be attracted to other men during their fertile days. Furthermore, men seem to be more attracted to women who are ovulating, possibly owing to physical changes (face, odour, voice pitch).

The complication here is that the contraceptive pill, used by numerous women around the world, can toy with these preferences. For example, women on the contraceptive pill show weaker preferences for masculine and symmetrical faces, and a recent study found that stopping the pill can influence relationship contentment, with satisfaction being linked to the husband's attractiveness.

Of course these are not hard and fast rules and can vary from person to person; for instance, our own self-perception of attractiveness can guide our preferences. But what they tell us is that attraction, governed by the quest for a mate whose genes will ensure the survival of our offspring (and thus our own genes), seems to be quite a self-centred process, at least from an evolutionary perspective. ■

Rachel David is studying for an MSc in Science Communnication

IMAGE: Flickr/Joop Van DijK/ Romance

THE MORAL COMPASS

Robyn Hopcroft explores the muddled world of morality.

There is a runaway trolley on the railway tracks. Five people are tied to the tracks and the only way to save them is to pull a lever that will switch the trolley to a side track where it will kill one person. What do you do?

Another runaway trolley is about to kill five people. The only way you can block the trolley is to push a man off a bridge, killing him and saving the five. What action do you take?

Welcome to the world of moral psychology. Philosophers have been puzzling over morality for millennia and more recently, psychologists have become interested in the workings of our moral compass. Most people would pull the lever, but they wouldn't push the man off the bridge. It seems we are repulsed by the idea of sacrificing another, but only when we get up close and personal. Interestingly, although most people judge moral dilemmas in the same way, they give different explanations for their judgments. Some think that rather than making reasoned moral decisions, we act intuitively and then make excuses for our choices after they've been made.

So if we have a moral gut instinct, are we are equipped with morality from birth? There is evidence of moral behaviour in early childhood, and a neurobiological basis for morality makes sense from an evolutionary perspective. We need to be able to cooperate to survive, so of course we should avoid immoral acts like hurting other people. But morality isn't purely innate. Most people agree on core moral issues, like murder and incest. Yet views on other matters, for example women's rights, vary across cultures and change over time. It seems that we are born with a framework for morality and build on this as we grow, internalising the values demonstrated by caregivers and wider society. Morality therefore forms an important part of social identity, strengthening our sense of belonging to social groups. Accordingly, people often use expressions such as 'British values' or 'Christian values' to link moral belief systems to specific communities.

IMAGE Flikr/Dikheel Aldikheel/ Moral compass

Neuroscientists approach morality from a different angle, using medical imaging technologies and studying patients with brain injuries. Their work indicates that many areas of the brain are active during moral decision-making, and emotion is heavily implicated as a motivator for moral behaviour. Functional MRI studies show that the emotional and reward learning centres of the brain are activated when choosing to act on a moral judgment, and patients with impaired emotional arousal do not always react in agreement with their moral judgments.

As scientists gain insight into the biology that underpins morality, neuroethicists have started asking how we could use this knowledge. Can we manipulate morality though scientific means? To some extent, yes. Some antidepressants have been shown to increase cooperation and fairness. Medications used to treat children with attention deficit hyperactivity disorder can improve impulse control and reduce antisocial behaviour. But what if we had the means, in the future, to apply more sophisticated interventions to the wider population? Deep brain stimulation and other non-invasive methods are used to treat conditions such as Parkinson's disease, but could potentially be adapted to enhance moral capabilities. Other suggested bioenhancers include embryo selection and genetic manipulation for favourable moral characteristics.

Some claim that applying extreme moral enhancements may remove our ability to decide how to behave, posing a threat to our freedom. If we can't choose to act immorally, then we lose part of ourselves. Others are in favour of enhancements. They think technology could be used to provide people with better tools for making moral decisions, giving people the choice to change who they are – to be better people. They highlight that our moral capabilities evolved to suit living in small communities, but that rapid technological advancement means that our behaviour can now have far reaching implications. Think of atomic weapons and climate change. Researchers at the Wellcome Trust-funded Oxford Centre for Neuroethics maintain that it is in our interests to develop safe moral enhancements, and that 'The future of life on Earth may well hinge on this policy.' ■

Robyn Hopcroft is studying for an MSc in Science Communication

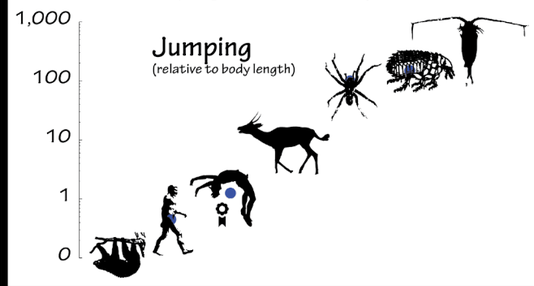
THE LIMITS OF HUMANITY

From speed and endurance to cognitive limits, Anne Petzold takes a look at just how far humans can go...

Illustrations by Oliver Barnstedt

MUSCLE UP!

The human record for high jump is 2.45m by Cuban Javier Sotomayor - 1.25 times his height - while most of us would not be able to jump half of that. The mammalian record holder is an elegant antelope called a Klipspringer, or 'rock jumper' in Afrikaans, which can jump about 10 times its height. Our mediocrity explodes when compared to animals that even take their body armour to the competition: arthropods. A copepod ('oar-feet') is a tiny crustacean that can jump 500 times its body size.



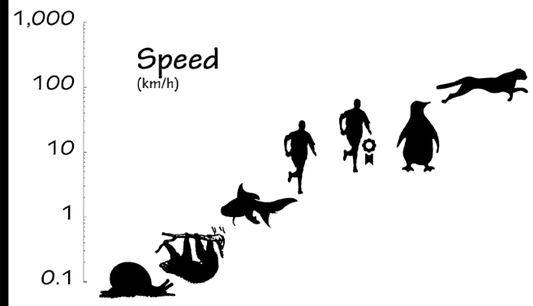
LIMITS OF LIFE

Humans normally live in fairly comfortable environments, above sea level in fresh air. But thanks to a mutation of a gene that protects against hypoxia, or lack of oxygen, Tibetans can survive on the Tibetan plateau, which at 4500m is one of the highest altitudes still inhabited by humans. However, humans are outdone by bacteria in black smokers (a type of underwater volcano), which need no oxygen at all. They live on hydrogen sulphide, an acid that turns our brain into juice in minutes. The existence of life so far removed from earth's atmosphere has led scientists to speculate that life may have started in such deep sea vaults.

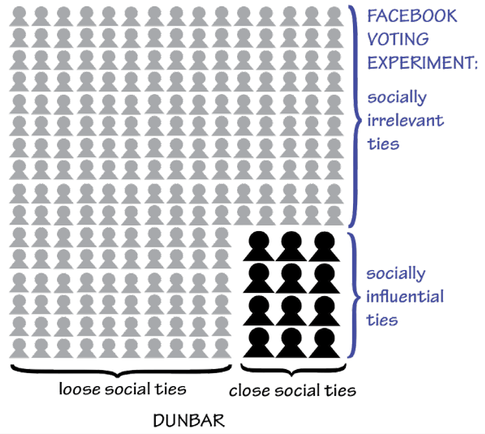
REPRODUCTION

The early demographer Thomas Malthus thought that richer people would have more children, just as other animals have more offspring when resources abound, but the opposite is true: we are approaching our lower limit. Almost half of humanity produces fewer than 2.1 children per woman, which a stable population requires. Global fertility will dip below the replacement fertility by 2020, still decades before the world population will stabilise. We might be the only animal that chooses to have fewer children than required to replace itself.

SPEED AND ENDURANCE



The human speed record is 35 km/h by Jamaican Usain Bolt. While most people would be happy to reach a third of that speed, the mammalian record holder is the Cheetah which can reach up to 100km/h sprinting. Some hunter-gatherers can also chase down an antelope, sometimes for days, until it is exhausted. The secret: sweating. While furry mammals need to stop and pant to cool down, humans shed heat on-the-run by sweating. Among land-dwelling mammals, we're quite tough: long distance runners such as Yiannis Kouros race from Sydney to Melbourne within five days - this might be as good as it gets in the animal kingdom!



SOCIAL BUBBLES

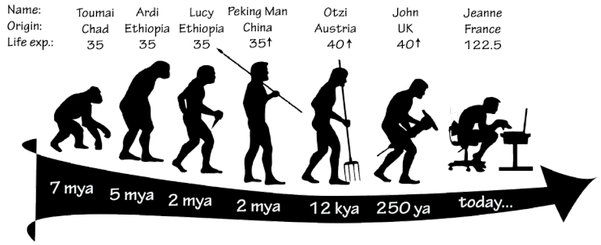
We have a cognitive limit to the number of people we relate to. We form close relations with about 12 people, or the size of an extended family, and loose relations with about 150 people. The adult Facebook user has about 200 friends (median). Can we really form close social ties with 200 people or more? Facebook tried to find out in the previous US mid-term election. That day, Facebook either sent an 'informational message' informing about the upcoming vote and providing an 'I voted' button, or a 'social message' with the additional information of six randomly selected friends who had already 'voted'. Only the 'social' message boosted the voting rate and only the inclusion of 10 or so 'close' friends made the difference, while the other 180 were ignored.

The study was hailed as an example of real-world impact by online networks, though it may just mean the exact opposite. Judge for yourself, or ask your friends.

THE MAGIC NUMBER SEVEN

50 years ago, George Miller published one of the most popular psychological studies of all time, claiming to have discovered 'the magic number 7 plus or minus 2'. The magic number refers to the number of items we can immediately recall, for example, a list of numbers such as: '6 7 3 2 0 6 0'. The human mind has a trick to boost this limited number: chunking. Many public phone numbers, such as that of Buckingham Palace (020 7766 7300), can comfortably be chunked into five items (020, 77, 66, 73, and 00) and we should be able to hold them in memory for at least enough time to type them into a phone. With our limited memory, chunking individual pieces of information according to patterns is key.

OUTLIVING OURSELVES



In 1888, Jeanne Calment met Vincent van Gogh and was not impressed. This would not be surprising, had Jeanne not lived another 100 years to tell the tale. At 122 ½ years, Jeanne is the oldest verified human who has ever lived. How old could a human person possibly be? Our average biological lifespan is estimated to be about 85 to 95 years. The life expectancy of children born today, however, may be even higher: our time may be the point where we outlive our biological lifespan to push our artificial, technology-assisted, lifespan. Whatever it may be, we fall short of the longest lived animal of all, a quahog clam called 'Ming', after the Ming dynasty that ruled China when it was born in 1499. Ming died more than 500 years later. ■

Anne Petzold is a second year PhD student studying Life Sciences

THE GREAT DEBATE: SHOULD WE SEQUENCE OUR GENOME?

Tom Gordon argues in favour of having our genome sequenced and Faiza Peeran argues against.

IMAGE: Flickr/Nathan Nelson/ DNA

When geneticist Craig Venter first suggested that it would soon be possible to sequence complete human genomes for $1000, the scientific community scoffed. This was the year 2000, and the eye-watering costs of the Human Genome Project had just been revealed; nearly $3 billion. For years the '$1000 genome' soundbite was a mocked pejorative; unable to shed its white elephant status.

Dissatisfied, the U.S. Government began to invest heavily in private genomic start-ups. Now, 15 years on, it's all change. Genetics giant Illumina offer complete genome sequencing for $1000 whilst 23andMe will test for several thousand of the most common genetic mutations for $99. However, whilst it is true that genome sequencing may lead to profound breakthroughs in medicine, its newfound accessibility brings into question the ethics of privacy and discrimination.

THE ARGUMENT 'FOR'

Today it costs more to have an X-ray on a broken ankle than to receive a complete genetic workup. It is bizarre to think that the most archaic, localised and routine medical practices are now more expensive than a complex and personalised procedure that, only ten years ago, cost nearly a hundred million dollars.

Every current healthcare model relies on 'reactive medicine,' where a person becomes sick and then receives treatment. Symptoms are the markers for disease and the sicker a person, the more obvious their condition. What if the suffering of the patient could be bypassed entirely? 'Predictive medicine,' where patients are routinely screened before they become symptomatic could become a reality with genomic testing. Thousands of conditions like heart disease have been found to have a strong genetic element. Treatment in advance of symptoms can lead to a much higher quality of life for the patient in the long term. As well as treatment, those who were predisposed to aggravated conditions such as obesity might be able to make meaningful and proactive changes to their lives as a counterbalance. Catching these long-term conditions early could not only lead to a more contented society, but also would likely significantly reduce the financial cost to already stretched health care systems.

Genomic sequencing could combine with next-generation medical procedures for particularly effective treatment for diseases like cancer. Current cancer detection methods like biopsies and lumbar punctures are uncomfortable and invasive for the patient, and are only able to detect a malignancy once it has reached a certain size. It has been theorised that that powerful nanoprobes could detect cancers at the microscopic level. Personalised drugs, created using the genetic sequence of the patient, could then deliver a highly specific and effective treatment.

Ultimately, it is possible that a worldwide genetic database could be constructed to identify a slew of heritable diseases. The 100,000 Genomes Project was launched in late 2012 to collate data from thousands of NHS patients into a workable index of genetic diseases. It is now known that 80% of the rarest diseases have some genetic element. With a complete directory, gene therapy would, one day, be able to eradicate famously debilitating and ultimately lethal diseases like Huntington's and cystic fibrosis.

THE ARGUMENT 'AGAINST'

It would be naïve to say that sequencing your genome comes without the risk of emotional cost, especially if you have family around you that may be affected by the results. Among other information, whole genome sequencing gives information about risks and predispositions individuals have to certain diseases. Many people may not want to know if they are at risk for a late-onset or behavioural disorder,

> **90% OF ADULTS WHO ARE AT RISK OF DEVELOPING HUNTINGTON'S DISEASE CHOOSE NOT TO HAVE A PREDICTIVE TEST DETAILING THEIR STATUS**

especially if they could do little to prevent it. We already know that 90% of adults who are at risk of developing Huntington's Disease choose not to have a predictive test detailing their status. Some may feel resigned to their fate if told, for example, that they are predisposed to a heart condition, which may give them a passive attitude and make them less inclined to take steps to prevent it. Other issues regarding this may also arise; would you be obligated to tell a relative that they are also at risk for a particular disease, even if they have opted not to test their own genome? If you had children who were at risk because you passed on mutated genes unknowingly, would they blame you for not finding out before you had had children? On the other hand, whole genome sequencing in healthy individuals may not offer any clinical information, as the data collected may be not be very meaningful. Another issue to consider is privacy and fear of genetic discrimination. If everyone sequenced their genome, there will be people who are shown to be predisposed to a certain disorder. There is the danger that insurance companies or employers will be able to access this information and potentially deny coverage or employment. It is also clear that as the technology develops, the criminal justice system would be able to make great use of DNA taken from crime scenes, for example.

However, should such personal information, such as your predispositions to certain diseases, be able to be routinely scrutinised in such cases, especially if it turns out you are not implicated in the crime? People may also be wary of the privacy involved in storage. With their genetic information effectively reduced and available as a computer file, many may feel anxious about the possibilities of such personal information being misused or stolen, especially since identity theft is already a very real and growing threat.

The availability of genome sequencing may also create an issue. Would the cost of testing mean that genome sequencing would only be available to those who could afford it? This could create an underclass of people who would be denied the chance to sequence their genome. They would be, for example, unable to have access to early, preventative healthcare to treat certain predispositions to disorders – which someone who can afford testing would be able to acquire. It's also important to remember that just possessing the ability to do something new does not create immediate justification for using it - especially in a case such as this, which is naturally awash with ethical issues and considerations. There are also the additional costs attached that are created by the impact of genome sequencing, such as genetic counselling or bioinformatics. ■

Tom Gordon and Faiza Peeran are both studying for an MSc in Science Communication

BOOK REVIEWS

by Eleanor Magson

DO NO HARM
BY HENRY MARSH

I hesitated for a while on purchasing this book. Anyone with a rudimentary knowledge of the ancient Greek medic Hippocrates knows where this title comes from (The Hippocratic Oath's first line), and that is precisely what put me off. My knowledge (and perceived interest) in clinical neurosurgery was woefully confined to Dr McDreamy's latest endeavours on Grey's Anatomy.

But I was converted. The book is fantastic. It is broken down into neat chapters each named after a brain tumour and centred on a surgery Marsh has carried out (Oligodendroglioma, Haemangioma, Astrocytoma). I imagine some of the descriptions of neurosurgery and brain anatomy might seem too detailed for some, but I found that Marsh's descriptions of his surgical tools tunnelling through brain tissue gave a better neuroanatomy lesson than I ever received.
Chapters are concise, well-written and intriguing, and it's easy to gobble up a handful in one sitting. Marsh, writes honestly and humbly; it is clear why he is so trusted by his patients. His work in Ukraine, where he provided free surgery for those who could not afford it, is a contrast against the bureaucratic nightmare of the modern NHS ('I have lost count of the number of different passwords I now need to get my work done every day').

Sometimes coming across as a bit of a grumpy old man, and certainly not shy of telling stories that paint a less than perfect picture of himself, it becomes clear that this is all because of his desire to help as many people as quickly as possible. It seems unlikely, but reading about his backstory (a degree in Philosophy, Politics and Economics), it appears that Marsh just fell into becoming a brilliant neurosurgeon, and now, into a brilliant writer. After reading this book, there is no-one else I would rather have operate on my brain (and write about it afterwards). ■

Eleanor Magson is studying for an MSc in Science Communication

by Anne Petzold

DATACLYSM
BY CHRISTIAN RUDDER

As CEO of OKCupid, one of the biggest dating websites worldwide, Christian Rudder is in possession of some BIG data. To fill the data pool to the brim, he also gathered a deluge of data from Facebook, Twitter, Reddit, and other social networks.

'Data', in the context of social media sites, captures how long we are lingering on a particular picture and whether we do or don't click a particular link, but also how we explicitly rate a particular content - whether we 'like' it, in the relatively anonymous context of online sites.

Online behaviour is less inhibited by convention than the behavior we observe in experiments or polls: for instance, imagine we asked someone on the street to rate another person's sex appeal, or whether they would consider themselves racist. We're unlikely to get an uncensored, honest answer. Being able to observe on a large scale what people actually like and do instead of asking them what they would like and do allows unique and deep insights into 'who we are - when we think nobody is looking' the subheading of this book.

This is one of the first works out there that transparently analyses big social data in a hilarious, yet thoughtful manner for the public – who are the actual, and perhaps unwitting, participants in this big social experiment. ■

Anne Petzold is a second year PhD student studying Life Sciences

EVENT REVIEWS

by Connie Orbach

CRAVINGS: A TASTY TREAT

How much do subliminal messages influence the way we eat? Why do we sometimes feel a need for a certain type of food? Do we really have a second brain?

Cravings is the newest offering from the Science Museum's Antenna Gallery. It appears to be an imitation of the junk food industry; everything is artificially coloured and overly cheerful, but far from real or 'natural', You're drawn in by the sugar coated donut but soon realise the true world that lies beneath. There are three main themes: the brain, the gut brain and gut bacteria. Through learning about the ways in which each of these react and change in response to what we eat, we can see how some food may really be controlling us.

There are things to smell, an ongoing live experiment and the world's first poo bank. Focusing on the brain's impact on what we eat and why, Cravings offers a refreshing take on a national health issue so often defined by our physical appearance. Instead of saying "eating makes you fat", it asks: why are we always so drawn to the things that are bad for us? In understanding our impulses better, can we re-claim control?■

Connie Orbach is studying for an MSc in Science Communication

by Eleanor Magson

THE HARD PROBLEM

Tom Stoppard's first play in nine years is a story of neuroscience and philosophy, altruism and egotism. We meet Hillary, who begins as an undergraduate student. She has applied for a PhD position at the fictional Krohl Institute for Brain Science, which she believes she will need a miracle to get in, and Imperial 'for the hell of it'.

Our characters, primarily Hillary and her antagonist Spike, conflict upon the most basic arguments of philosophy – dualism versus materialism, and altruism versus egoism. This is a play which sets out to make you think, something which it does not shy away from. It would perhaps become tedious were it not for the enthusiasm and conviction of Hillary. The discussions and debates between characters might come off as pretentious, but Stoppard settles them in a believable reality of a brain institute.

The play could not be described as particularly dramatic, but this is simply not its style. The audience is constantly questioning the altruistic motives of the characters; personal and professional. Its charm lies in having its characters constantly debating and questioning each other, meaning that it manages to catch the audience, who are kept wondering, and second-guessing, throughout. ■

Eleanor Magson is studying for an MSc in Science Communication

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